# SENSOR FOR MEASURING A GAS CONCENTRATION OR~~F~~ ION CONCENTRATION

## PRIORITY INFORMATION

This application claims priority from German application 102 54 523.5, filed November 22, 2002.

## BACKGROUND OF THE INVENTION

This invention relates in general to sensors and in particular to a sensor for measuring a gas or ion concentration~~ or ion concentration according to the preamble of Claim 1~~.

~~Such a sensor is known from DE 101 18 367 A1, which originated with the applicant.~~

Sensors with field-effect transistors (FETs) for measuring gas concentrations, ~~which use as~~ where the gate of the FET ~~a~~ may be a gas-sensitive layer whose work function depends on an ambient gas concentration, are known for example from U.S. Patent 4,411,741.

Sensors with FETs ~~field-effect transistors using as~~for measuring ion concentrations, where the gate of the FET may be an ion-sensitive layer whose potential depends on the ionic concentration of an ambient liquid or ~~an ambient~~ gas, are ~~among the~~ known ~~sensors~~ for example from ~~measuring ion concentrations.~~ U.S. Patent 5,911,873~~ discloses one such ion-sensitive FET (ISFET)~~.

Such sensors may ~~are~~ generally be fabricated by counter-doping a semiconductor substrate ~~so as~~ to form therein ~~generate in it~~ a drain and a source and growing or depositing an insulating layer on the substrate between the source and the drain. An ion-sensitive layer can be applied directly onto th~~is~~e insulating layer. A gas-sensitive layer can be made a certain distance away, ~~;~~ this configuration being known as ~~is called~~ a suspended-gate FET (SGFET).

Alternatively, a gate can be applied to the insulator and controlled capacitively by a gas-sensitive gate formed ~~made~~ a certain distance away. Such a sensor, known as ~~called~~ a capacitively controlled FET (CCFET), is described for example in German Patent DE 43 33 875 C2.

A disadvantage of these configurations may be ~~is~~ that after a certain time, surface conductivity ~~that~~ may ~~is always present~~ pulls a ~~the~~ potential ~~over~~ of the FET to a ~~the~~ potential that is present on the gas-sensitive gate, causing the drain-source current to drift. To prevent this, a conductive ring, or ~~also called a~~ guard ring, which can be set to a ~~well-defined~~predetermined potential, may be ~~is conventionally~~ laid around the FET. As ~~In~~ such, ~~a configuration,~~ the channel region of the FET may assume ~~takes on~~ the potential of the guard ring after a certain time because of the surface conductivity of the region between the guard ring and the channel region. The distance between the guard ring and the channel region of the FET and the conductivity of the surface may define the time required for the channel region to take on the guard ring potential, thus establishing ~~the minimum possible~~ a relatively small concentration change per unit time that a gas signal for detection may have ~~in order~~ to be registered. This distance governs the size and ~~hence also~~ the manufacturing costs of such a sensor.

What is needed is a ~~The goal of the invention is to create a further~~ sensor that can be manufactured at low cost, has relatively small dimensions, and achieves ~~nevertheless guarantees~~ a relatively high degree of accuracy of measurement for a ~~the~~ change in gas or ion concentration as a function of time, and i~~. I~~n particular where~~,~~ the surface resistance between the guard ring and the FET ~~is to~~ may be made higher, so that the ~~minimum~~ rise in concentration per unit time for a detectable gas signal ~~is~~ may be increased.

## SUMMARY OF THE INVENTION

~~This goal is achieved with a sensor according to Claim 1.~~

~~The dependent claims describe preferred developments.~~

A field-effect transistor used as a sensor for measuring a gas or ion concentration may allow for ~~Thus, according to the invention,~~ the surface conductivity between the guard ring and the FET to be ~~is in~~decreased in a relatively ~~surprisingly~~ simple way without any relatively large increase in the physical size of the circuit. ~~it being necessary to make the circuit larger in size.~~ ~~The invention provides for~~ Rings may be arranged~~ing~~ around the FET structures, where the rings may be ~~preferably rings, that are~~ defined by a surface material different from the remaining surface material and thus having different surface conductivities and being able to form contact resistances. ~~Additionally,~~

S~~s~~urface profiling ~~according to DE 101 18 367 A1~~ can also ~~further~~ be provided ~~in order~~ to increase ~~further~~ the RC time that may describe~~s~~ the equalization of the FET potential to the potential of the guard ring without impairing~~ment~~ ~~of~~ the functionality of the sensor configuration by the ~~this~~ surface profiling. Such surface profiling may additionally further lengthen~~s~~ the RC time. Through ~~With the~~ use of surface profiling, the raised regions may ~~are to~~ have a surface conductivity different from, for example ~~preferably~~ smaller than, the lowered regions.

The ~~According to the invention,~~ surface profiling may ~~can~~ be formed ~~fashioned~~ in a simple manner ~~way~~ by forming ~~additionally fashioning~~, on a previously generated thick oxide layer, elevations spaced a ~~some~~ distance apart.

The ~~According to the invention, the preferably~~ annual structures arranged on the thick oxide layer and defined by a surface material different from the remaining surface material may have different surface conductivities and ~~therefore~~ thus may form different, for example ~~preferably~~ higher, contact resistances. The overall effect may be ~~of the invention is~~ to increase

the surface resistance between the guard ring and the FET so that the ~~minimum~~ concentration rise per unit time of a gas signal may be ~~is~~ increased.

~~The fashioning even of larger elevations in the air gap between the sensitive gate layer and the thin oxide layer above the channel region does not present any problems as a rule.~~

~~In what follows, some embodiments of the invention are explained in greater detail on the basis of the drawings, in which:~~

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

F~~igure~~IG. 1 is a top view of an embodiment of a sensor ~~according~~for measuring a gas or ion concentration ~~to one embodiment of the invention~~;

F~~igure~~IG. 2 is a section along line A-A' in F~~igure~~IG. 1;

F~~igure~~IG. 3 is a section ~~similar~~through an embodiment of a sensor ~~to that in Figure 2 but through a different sensor~~; and

F~~igure~~IG. 4 is a top view of ~~a~~ an ~~second exemplary~~ embodiment of a sensor for measuring a gas or ion concentration ~~according to the invention~~.

## DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGs. 1 and 2, ~~O~~on a substrate 11 of a first charge-carrier type, for example ~~made of~~ n-doped silicon, a gas sensor may have ~~has~~ a source 2 and a drain 3 of a second charge-

carrier type, for example ~~made of~~ p-doped silicon, which may be formed ~~are fashioned~~, for example, by ion implantation.

The ~~S~~source 2 may have ~~has~~ a source terminal 6 and the drain 3 may have ~~has~~ a drain terminal 5. In the substrate 11 between the source 2 and the drain 3 there ~~is~~ may be a channel region 4~~,~~ on which a thin oxide layer 13 may be formed~~is fashioned~~. Insulator layers 14, for example thick oxide layers 14, may be formed ~~are fashioned~~ on the source 2 and the drain 3.~~,~~ A ~~a~~ guard ring 1 made of a conductive material may be ~~being~~ applied onto the~~ir~~ surfaces of the source 2 and the drain 3.~~,~~ The ~~which~~ guard ring 1 may encircle the ~~, as shown in the top view of Figure 1, runs around~~ channel region 4 and can be set to a predetermined ~~well-defined~~ potential.

Arranged on lateral insulator regions 9 may be ~~is~~ a gas-sensitive gate layer 8 whose potential depends on an ambient gas concentration. An air gap 10 may be formed ~~is fashioned~~ between the gate layer 8 and the thin oxide layer 13. The ~~T~~thin oxide layer 13 can be for example 3-50 mm thick and may function~~acts~~, together with the air gap 10, as a gate dielectric. Changes in the ~~gas~~ concentration of the ambient gas can thus be detected as changes in the source-drain current of the FET.

Between the thin oxide layer 13 above the channel region 4 and the guard ring 1 there may be ~~is~~ a ~~special~~ surface structure by which the surface resistance between the guard ring 1 and the FET ~~is~~ may be increased. Through suitable layer deposition steps and the use of photomasks as well as subsequent etching, ~~well-defined~~ materials, for example in the form of one or a plurality of ring structures 20, may be ~~are~~ arranged on the thick oxide layer 14 or embedded partially or fully therein. ~~These ring structures are identified by reference character 121 in Figure 1 and Figure 2.~~ The ring structures 20 can be formed for example ~~fashioned~~ as circular rings, ~~or,~~

~~as shown in Figure 1, as~~ quadrilaterals or ~~also~~ polygons. Aluminum or aluminum with a copper content may be a suitable ~~is a candidate~~ material for the ring structures 20, such~~o~~ that the ring structures 20 ~~12~~ form an aluminum oxide on their surface upon exposure to ambient air. ~~This has the effect that~~As such, the resistance on the surface between the guard ring 1 and the channel 4 may be ~~is~~ increased, such~~o~~ that the RC time required for equalization of the FET potential to the guard ring potential may be ~~is~~ prolonged.

F~~igure~~IG. 3 illustrates ~~shows~~ a sensor that is somewhat similar to the sensor of ~~one in~~ F~~igure~~IG. 2. In the sensor of FIG. 3, the ~~There, however,~~ ring structures ~~12~~ 20 may rise as elevations 7 above the ~~rest of the~~ surface 15 of the thick oxide layer 14 ~~in the direction~~ toward the air gap 10. The regions 12 lying between the~~is~~ elevations ~~12~~7~~, that is, raised ring structures 20,~~ may be ~~are~~ identified as depressions 12. The r~~R~~aised ring structures 20 may have a surface conductivity lower than that of the depressions 12. The process of ~~The~~ forming~~fashioning of~~ the elevations 7 and the depressions 12 may lead~~s~~ to surface profiling of the thick oxide layer 14. The profiling of the surface 15 of the thick oxide layer 14 can ~~in particular~~ be formed ~~fashioned~~ by the application of layers on the thick oxide layer 14 through appropriate deposition steps followed by etching steps defined by photomasks to uncover the depressions 12. The ~~E~~elevations 7 applied by deposition may be ~~are~~ made of a material different from that of the thick oxide layer 14. A material with a low surface conductivity, such as aluminum or aluminum with a copper content, may be ~~is~~ used for surface profiling. Upon contact with air, ~~this forms~~ an aluminum oxide is formed on the surface, so that the surface conductivity may be ~~is markedly~~ lowered. The ~~T~~thick oxide layer 14 may be ~~is~~ uncovered where the layers ~~were~~ are etched~~, that is,~~ in the depressions 12.

---

~~1 The reference characters in the translation follow those in the text of the original specification, not those used in~~

~~It is additionally pointed out that~~ The thin oxide layer 13 can also be implemented as a capacitance. ~~For purposes of disclosure in this connection, reference is made to the complete content of the patent application titled "Sensor for Measuring an Ion Concentration or Gas Concentration," filed with the German Patent and Trademark Office by the same applicant on the same date as the present application.~~

Another ~~A second~~ embodiment of the sensor ~~invention~~ is illustrated ~~shown~~ in ~~Figure~~ FIG. 4~~3~~. Therein, ~~In this exemplary embodiment,~~ the field-effect transistor formed from the source 2 and the drain 3 may be ~~is~~ spatially separated from the air gap 10 between the gate layer 8 and the channel region 4. The ~~G~~gate 16~~2~~ of the field-effect transistor may be ~~is here~~ led in an insulated manner ~~fashion~~ via an electrode 19 below the elevations 7 into the channel region 4 below the air gap 10.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is:

~~List of Reference Characters~~

~~1 Guard ring~~
~~2 Source~~
~~3 Drain~~
~~4 Channel region~~
~~5 Drain terminal~~
~~6 Source terminal~~
~~7 Elevations~~

---

~~the Drawings—Translator.~~

~~8 Gas-sensitive gate~~

~~9 Insulating layer~~

~~10 Air gap~~

~~11 Substrate~~

~~12 Depressions~~

~~13 Thin oxide layer~~

~~14 Thick oxide layer~~

~~15 Surface~~

~~16 Electrode~~

~~20 Regions/rings with increased surface resistance~~